Clinical Neurophysiology 125 (2014) 2337–2343

Contents lists available at ScienceDirect

Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

Impact of sleep on the localizing value of video EEG in patients with refractory focal seizures – A prospective video-EEG with EOG and submental EMG study

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ARTICLE INFO

Article history:
Accepted 11 March 2014
Available online 4 April 2014

Keywords:
Sleep
Video EEG
Localization
Refractory
Focal seizures
Focal epilepsy

HIGHLIGHTS

- Sleep may have important implications for presurgical assessment of refractory epilepsy.
- The relationship and the role sleep plays in the occurrence and spread of seizures is unclear.
- We comprehensively assess the role of sleep in Video Electroencephalography (VEEG) localization of seizures, which may help in the management of difficult presurgical cases.

ABSTRACT

Objectives: To examine the role of sleep and its stages on the localizing value of video EEG in the evaluation of refractory focal seizures.
Methods: Video-electroencephalographic (VEEG) evaluation with additional polygraphic recording was carried out for 70 consecutive patients with refractory focal epilepsy, undergoing pre-surgical evaluation, over a two-year period. Localization of video EEG for each seizure was made based on clinical, ictal and interictal data. Seizure localization in each patient was assessed for concordance with MRI and other imaging data (SPECT, PET) for both wake and sleep seizures. Interictal discharges in sleep and wake were similarly compared for concordance with imaging data.
Results: A total of 608 seizures were recorded in 70 patients, 289 in sleep. Overall, concordance with imaging data was found in 218 out of 322 wake seizures (67.8%) and in 157 out of 286 sleep seizures (54.8%) ($p = 0.0314$). On analyzing the subset of patients with seizures recorded in both wake and sleep states (total 279 seizures recorded, 113 out of sleep), concordance was observed in 93 out of 166 (56%) wake seizures and in 80 out of 113 (70.7%) sleep seizures (OR 2.03, 95% CI 1.17 to 3.56; p 0.007). Interictal discharges were more common and more precisely localizing in sleep, mostly in stage N2.
Conclusions: This prospective VEEG-PSG study demonstrates the role of sleep versus wake state in the localizing value of different components of long-term VEEG recording for patients with medically refractory epilepsy. Our findings show that while wake state ictal EEG has more localizing value in a mixed group of patients, sleep ictal and interictal EEG is significantly more useful in patients who have seizures recorded both during wake and sleep states. In addition, interictal discharges recorded during NREM sleep have high localizing value.
Significance: This is only the second study elucidating the effect of sleep on the localizing value of video-electroencephalographic evaluation of patients with medically refractory focal epilepsy; mainly revealing high value of sleep interictal discharges and that sleep ictal recording has two times higher localizing value than wake ictal recording, among patients in whom seizures are recorded in both states.

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http://dx.doi.org/10.1016/j.clinph.2014.03.021
1388-2457/

1. Introduction

Nearly 20% of patients with epilepsy have seizures that are refractory to treatment. Epilepsy surgery offers a ray of hope to these patients and has been globally accepted as a potential curative measure in patients with substrate related epilepsy.

Video electroencephalography (Video EEG) and MRI have proved to be simple and affordable non-invasive pre-surgical evaluation strategies for substrate related epilepsy and this has resulted in the creation of epilepsy surgery programs in developing countries (Radhakrishnan et al., 2008). The success of epilepsy surgery programs in a developing country depends upon the ability to select ideal surgical candidates using these two modalities (Sylaja and Radhakrishnan, 2003; Asadi-Pooya and Sperling, 2008).

Out of 50 million people with epilepsy globally, 80% live in resource poor countries. India has over one million people with medically refractory epilepsy, of which nearly one half are potential surgical candidates (Winkler et al., 2007). According to a survey, in 26 of 142 (18.3%) economically disadvantaged nations, at least one center regularly conducted epilepsy surgeries, compared with 18 of 24 (75%) developed countries (Wieser and Silfvenius, 2000). Thus only a minority of potential surgical candidates in our country ever get a chance to undergo presurgical evaluation and surgery (Radhakrishnan, 2009). Many reasons are cited for this. Very few centers in the country provide facilities for epilepsy surgery. Availability of investigative facilities like EEG and neuroimaging instruments may be severely restricted. Where facilities like video EEG exist, there are long wait lists, minimally trained technologists and patients requiring prolonged recordings to achieve seizure focus localization.

A major rate limiting step in presurgical evaluation of patients is VEEG monitoring, which has emerged as the most important test for localization of seizure foci, along with neuroimaging. Often, localization on VEEG is confounded by various factors like very rapid generalization of focal seizures, deep-seated seizure foci, multiple seizure foci, multiple seizure types and sleep.

Sleep may have important implications for presurgical assessment; because seizures recorded during wakefulness may yield a different seizure localization from those recorded during sleep, which often yield information different from that obtained out of ictal wake state recordings. The propensity of various types of focal seizures to occur in different stages of the sleep–wake cycle has been clearly shown (Herman et al., 2001). In addition, the lateralizing and localizing value of interictal epileptiform discharges (IEDs) has also been reported (Sammaritano et al., 1991; Malow et al., 1998; Ochi et al., 2011).

This study was conducted with the objective of comprehensively assessing the role of sleep and its stages on the overall localizing value of VEEG studies for presurgical evaluation of refractory focal epilepsy.

2. Materials and methods

This study was approved by the Ethics Committee of the All India Institute of Medical Sciences. It was prospectively conducted from Jan 2010 to June 2012. Patients with medically refractory epilepsy i.e., epilepsy patients in whom seizures were persisting $\geqslant 1$ per month for at least 6 months prior to assessment, on optimum doses of $\geqslant 2$ AEDs with good compliance; who were admitted the epilepsy monitoring unit under one unit of the Department of Neurology at our institution formed the study group. Patients with co-morbid neurological illnesses, which could affect sleep in epilepsy patients viz. stroke, encephalitis/meningitis, metabolic encephalopathy were excluded. Patients with known primary generalized epilepsy, known primary sleep disorders and those with non-organic seizures were also excluded.

2.1. Clinical evaluation

At admission into the epilepsy monitoring unit, history of all patients was re-evaluated, a pre-structured clinical proforma was filled, noting demographic details, epilepsy characteristics like age at onset, duration, frequency, seizure semiology, propensity of seizures to occur during sleep versus wake stages, or immediately on awakening, other precipitating factors, anti-epileptic drugs (AED) history, other neurological impairment and history of antecedents in the past.

2.1.1. Investigations for pre-surgical evaluation

2.1.1.1. Neurophysiologic evaluation.

2.1.1.1.1. Data acquisition. All patients underwent video-electroencephalographic (VEEG) recording following admission into the epilepsy monitoring unit. Continuous recordings were performed over several days with scalp electrodes, video, and audio using digital long-term monitoring and sleep systems (Nicolet One Viasys®) with additional anterior temporal electrodes placed in all patients, as per standard protocol of our center. Scalp electrodes were placed by using collodion according to the 10–20 International System. Sphenoidal electrodes were implanted in suspected temporal lobe epilepsy, whenever considered useful. No activation procedures were used and anti-epileptic drug (AED) tapering was carried out for patients, according to individual requirement for optimal yield of the long term monitoring. Video of the seizures were shown to the caregivers and confirmed to be the habitual seizures in all the cases.

Throughout the recording, submental EMG, EOG electrodes and chest and lower limb piezoelectric belts were also applied for polygraphic recording in order to collect adequate sleep related data. Seizure occurrence was noted with respect to different phases of sleep.

2.1.1.1.2. Interpretation of neurophysiologic data. The VEEG studies were analyzed during the patient's admission and again prior to discussion of each patient's candidature for epilepsy surgery. All analyses were carried out independently by GS and SS and then discussed in detail prior to finalization of conclusion of each study. The clinical semiology and ictal EEG correlates of all recorded events were noted and individually assigned localization. The interictal EEG was reviewed and all abnormalities were charted systematically, for at least 1 hour each in wake and sleep stages, the latter including both NREM and REM sleep states, for each 24 hours of recording. Sleep scoring was carried out according to AASM guidelines (Silber et al., 2007). The state, in which events occurred, was charted for all events.

2.1.1.1.3. Neuro-imaging. All patients had magnetic resonance imaging (MRI) studies of the brain, either prior to VEEG or during the admission in the EMU. Ictal SPECT was planned and obtained for all patients with extra-temporal epilepsy, hemispheric or bilateral imaging findings and all patients with discordant findings on VEEG and MRI. PET scans of brain were obtained for all patients with normal MRI, and those with discordant VEEG and MRI, where strong suspicion of a structural pathology other than the one visible on MRI, was present.

The following information was recorded for each focal seizure:

(a) seizure type (focal/generalized/focal with generalization),
(b) region of onset if known,
(c) epilepsy syndrome diagnosis, if possible,
(d) time of EEG and clinical seizure onset,
(e) sleep/wake state at seizure onset.

2.1.1.1.4. Definitions. Temporal lobe epilepsy (TLE) was defined on the basis of clinical seizure semiology of temporal lobe auras (Jobst et al., 2000), automatisms of limbs or orofacial musculature (Rusu et al., 2005), unresponsiveness, limb dystonia and amnesia (Wieser, 2004). The history of febrile seizures or other antecedents in early childhood and the characteristic course with initial latent period and stuttering increase in seizure frequency, whenever present, were used as supportive to this diagnosis and for defining the sub-group of patients with mesial temporal lobe epilepsy (MTLE).

Frontal lobe epilepsy was defined based on history of brief seizures, absence of aura, abrupt onset and offset, clustering and predominant occurrence in sleep, with semiology of bizarre proximal automatisms, without postictal symptoms (Ryvlin et al., 2006).

Wake, NREM and REM stages: These were scored according to the AASM criteria (Silber et al., 2007).

2.1.1.1.5. Data entry. At the time of review it was determined whether the patient was awake or asleep and, if asleep, the sleep stage. At the end of the study, the following information was charted and entered onto MS Excel spread-sheets. Two different types of datasheets were prepared:

I. Data on overall VEEG localization for all patients, its concordance with imaging and the most useful state during VEEG recording:
1. Clinical localization – right/left, frontal/parietal/temporal/occipital.
2. Ictal EEG localization – right/left, frontal/parietal/temporal/occipital.
3. Interictal EEG localization-noted for every 24 hours of recording (at least 1 hour of clean awake and 1 hour of clean sleep state). Types (populations) of interictal discharges (IEDs) and their percentage were noted.
4. Overall VEEG localization: right/left, frontal/parietal/temporal/occipital. Along with this, the most useful stage, i.e. wake or sleep and the most useful VEEG component i.e. clinical, ictal or interictal which led to final VEEG localization. Overall VEEG correlation with imaging (MRI Brain ± SPECT ± PET) for concordance.

II. Datasheet on localization of all individual events recorded on VEEG and the state with maximum concordance between VEEG and imaging:
1. For every event, occurrence in awake or sleep state, and if in sleep, sleep stage was noted.
2. Concordant versus discordant seizures were compared for occurrence during wake versus sleep state (NREM or REM) and total number of concordant and discordant seizures were noted in wake and sleep.

Localization of video EEG was made based on clinical, ictal and interictal data. Concordance was assessed between clinical and EEG findings in all seizures.

During VEEG interpretation, the component (clinical semiology, ictal EEG or interictal EEG) which formed the main basis of seizure localization was termed 'most useful VEEG component'.

2.2. Statistical analysis

All data was reviewed with descriptive analysis primarily, since this facilitated comparison of localizing value of various neurophysiologic components recorded in different states.

Unpaired and paired Student's '*t*' test or chi square tests were used to assess statistical significance between parameters, wherever appropriate and a p value of <0.05 was considered to be significant.

3. Results

A total of 70 patients (39 males, 31 females) with an age range of 4–47 years (mean 22.1 ± 9.4) were recruited during the study period.

3.1. Epilepsy characteristics

The mean age at onset was 11.2 ± 7.7 years. The mean duration of illness was 11 years and mean frequency was 39 seizures per month. History of antecedent insult like perinatal hypoxia, febrile seizures and head injury was present in 29 patients (41.4%). The epilepsy type, decided on the basis of clinical features and radiology was observed to be distributed as follows: temporal lobe epilepsy constituted two thirds (45 patients) and frontal lobe epilepsy around one fifth (12 patients). Hippocampal sclerosis was the most common lesion, found in one fifth of the patients, followed by cortical dysplasias. Antecedent history of febrile seizures, perinatal insult, head trauma or encephalitic illness, was found in 40% patients. Mean duration of epilepsy for all patients was around 10 years (Table 1).

To check for concordance of VEEG data, MRI brain with relevant sequences was available for all patients, SPECT was available for 56 and FDG PET was available for 12 patients. For 50 patients (71.4%) polysomnography data was available. For the remaining 20 patients, sleep stage scoring had been carried out solely through EEG findings.

3.2. Video-EEG-PSG data

A total of 608 seizures could be recorded for the 70 patients included (average 8.6 seizures per patient, range 1–40). Among these, 286 seizures occurred in sleep.

3.3. VEEG yield in wake state versus different stages of sleep

Twenty-three patients (32.8%) had seizures in wake state only, 16 (22.8%) in NREM sleep only and 30 (42.8%) had seizures both in wake and NREM sleep. Only one patient had seizures recorded during REM sleep.

In all, 56% seizures recorded were in wake state, 4% in N1 NREM sleep, 37% in N2 NREM sleep, 2% in N3 NREM sleep and 0.5% were in REM sleep.

Table 1
Baseline characteristics.

Parameter	Patients (n = 70)
Age	22.1 ± 9.4 yrs
Age at onset	11.2 ± 7.7 yrs
Epilepsy type-clinical	
Frontal	12 (17.1%)
Temporal	45 (64.2%)
Parieto-occipital	10 (14.2%)
Central	1 (1.4%)
Not known	2 (2.8%)
Antecedent history	
Yes	29 (41.4%)
No	41 (58.5%)
Most useful STAGE for localization-	
Wake only	23 (32.8%)
NREM sleep only	26 (37.1%)
REM sleep	1 (1.4%)
Wake and NREM sleep	20 (28.5%)
Most useful VEEG Component for localization	
Clinical Semiology	5 (7.1%)
Ictal EEG	49 (70.0%)
Interictal EEG	16 (22.8%)

Patients of frontal lobe epilepsy had more frequent seizures during sleep (mean 6.3) as compared to temporal lobe epilepsy (mean 3.5) and this difference was statistically significant ($p = 0.049$).

3.4. Relation of wake versus sleep states to concordance

Concordance with imaging data was found in 218 out of 322 wake seizures (67.8%) and in 157 out of 286 sleep seizures (54.8%) ($p = 0.0314$) (Table 2).

Evaluation of concordance for individual patients ($n = 70$), showed that the 'most useful stage' for VEEG localization was wake stage, in 23 patients (32.8%), NREM sleep in 26 (37.1%) and both wake and NREM sleep in 20 patients (28.5%).

Also, ictal EEG onset was observed to be 'focal' in 139 wake seizures (53%), as compared to 65 sleep seizures (32%) ($p = 0.0001$).

A comparison of temporal and extratemporal epilepsy characteristics is shown in Table 3. The localization of seizures into generalized, lateralized, regional and focal has been elaborated in Table 4 and its relation to sleep stage has been shown in Table 5.

3.6. Subset of patients with both sleep and wake seizures

On analyzing the subset of patients with seizures recorded in both wake and sleep states; among 30 patients, there were a total of 279 seizures, 113 out of sleep. Twenty-two patients among these had TLE and the rest had ETLE. Concordance was observed in 93 out of 166 (56%) wake seizures and in 80 out of 113 (70.7%) sleep seizures (OR 2.03, 95% CI 1.17 to 3.56; p 0.007). An example is shown in Fig. 1.

3.7. Role of sleep in the localizing value of interictal EEG

IEDs were found in 57 patients during sleep state and in 37 patients in wake state; being most common in N2 stage of NREM sleep. Of these, IEDs lateralized to the side of the lesion seen on imaging, were recorded in sleep, in a total of 54 patients (77.1%) and in wake state in 35 patients (50.0%).

Similarly, focal IEDs concordant with imaging data, were recorded during sleep, in 45 patients (64.2%) and in wake state in 25 patients (35.7%).

Table 2
VEEG localization parameters in sleep and wake.

Discharges	Wake	Sleep	p Value
CONCORDANCE in seizures	218 (67.8%)	157 (54.8%)	0.03
CONCORDANCE in seizures (in patients with both sleep and wake seizures)	93 (56%)	80 (70.7%)	0.007
Focal ICTAL EEG onset in seizures	139 (53%)	65 (32%)	0.0001
Abnormal INTERICTAL EEG (no. of patients, %)	45 (64.2%)	25 (35.7%)	0.002

Table 3
Comparison between temporal and extratemporal epilepsy patients.

Parameter	Temporal ($n = 45$)	Extratemporal ($n = 25$)	p Value
Total number of seizures (mean, range)	9.6 (2–31)	8.1 (1–40)	0.88
Sleep seizures	5.0 (0–31)	3.5 (0–40)	0.36
Wake seizures concordant (mean)	3.4	2.4	0.14
Wake seizures discordant (mean)	1.1	1.8	0.04
Sleep seizures concordant (mean)	2.1	2.4	0.66
Sleep seizures discordant (mean)	1.0	2.4	0.03

Table 4
Localization in patients and seizures.

Localization	Patients ($n = 70$)	Seizures ($n = 608$)
Generalised	6	127
Lateralised	13	94
Regional	17	143
Focal	34	244

Table 5
Seizure classification in each sleep stage ($n = 483$).

Localization	Wake	N1	N2	N3	REM
Focal	138	2	52	11	0
Regional	56	13	26	1	0
Lateralised	25	6	27	4	2
Generalised	31	10	40	12	0

Seven patients (10.0%) had 2 distinctly different populations of IEDs, in wake (with the exception of bi-temporal discharges in patients with hippocampal sclerosis on MRI), while in 12 patients, a different IED population was found during REM sleep, concordant with the overall VEEG data in 7 patients and discordant in 5.

The 'most useful video-EEG' element in ascertaining localization was clinical semiology in 5 patients (7.1%), ictal EEG in 49 patients (70%) and interictal EEG in 16 (22.8%) patients.

In 5 out of 20 patients with seizures both in sleep and wake, localization was based completely on the sleep IEDs, with no contribution from wake ictal or interictal EEG. An example is shown in Fig. 2.

4. Discussion

The results of the present study provide information on the role of sleep in the localizing value of VEEG studies of patients with refractory focal epilepsy undergoing presurgical evaluation. Our results reveal several important findings. Firstly, in a heterogeneous population of the patients with medically refractory epilepsy undergoing VEEG, who had seizures recorded in either sleep, wake state or in both states, the VEEG localization in wake seizures was significantly better than sleep seizures. However, among patients in whom seizures were recorded both during wake and sleep states (TLE as well as ETLE), sleep seizures were twice as localizing as wake seizures. Thirdly, significantly higher number of wake seizures showed regional rather than non-lateralized ictal EEG onset. Finally, focal IEDs, concordant with imaging data, were significantly more common in sleep than in wake. Our study confirmed some established facts, viz. sleep seizures were more frequent in frontal lobe epilepsy and Stage N2 of NREM sleep was associated with the majority of sleep seizures (Minecan et al., 2002).

While there are only a few studies in published literature addressing the issue of sleep among patients undergoing VEEG monitoring (Bazil and Walczak, 1997; Crespel et al., 2000; Herman et al., 2001; Minecan et al., 2002; Buechler et al., 2008) as pre-surgical evaluation for medically refractory epilepsy; ours is the first study to comprehensively assess the role of sleep in the localizing value of VEEG. Only, Beuchler et al. reported their observations on the localizing value of VEEG recorded during sleep versus wake, in a much smaller number of highly selected population of seizure free post-surgery TLE patients (Buechler et al., 2008).

4.1. Role of sleep in yield of VEEG

Our finding of significantly higher yield of seizures and IEDs during sleep VEEG is in agreement with previously reported

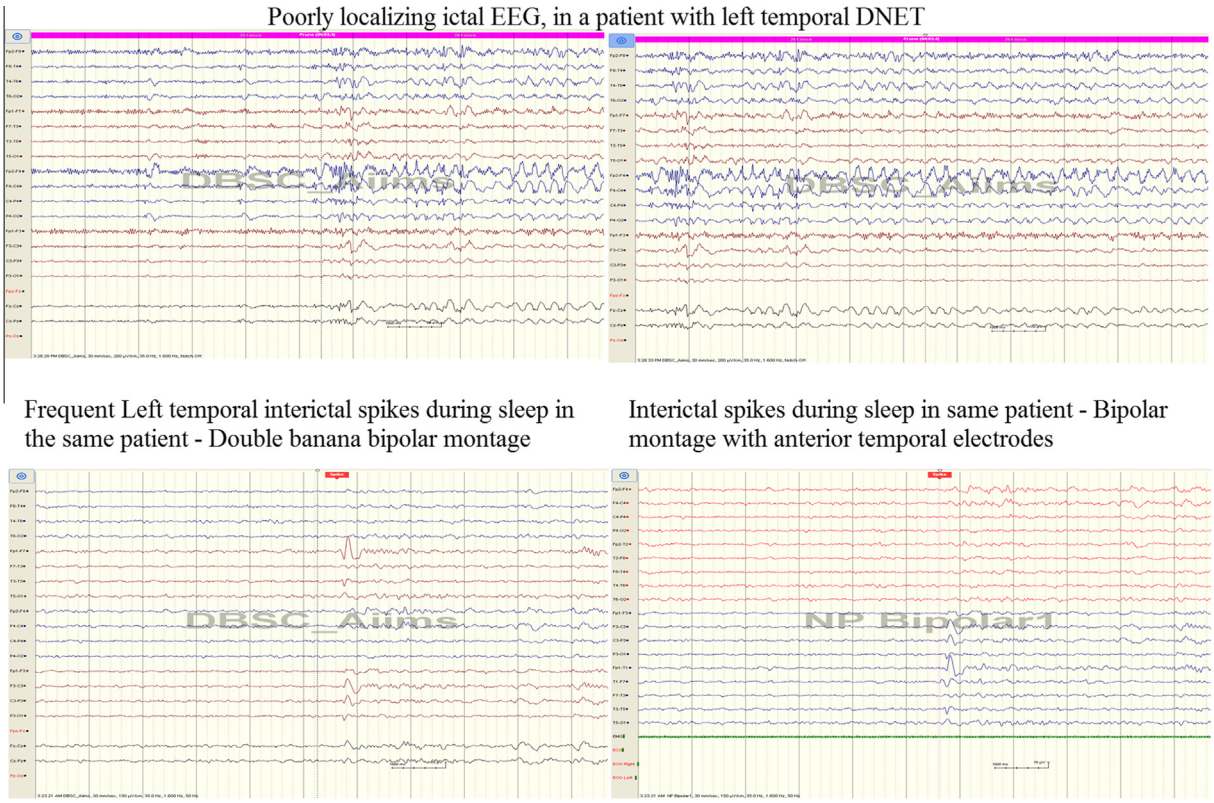

Fig. 1. Value of sleep interictal EEG for localization.

observations. Crespel and colleagues studied 15 patients each of frontal and temporal epilepsy, recording VEEG and PSG and concluded that FLE seizures occur mainly in sleep and TLE in wake (Crespel et al., 2000), a finding similar to ours.

In another VEEG study, Sinha et al. studied 57 refractory epilepsy patients with both sleep and wake seizures and showed that frontal lobe seizures were brief and more likely to generalize secondarily (Sinha et al., 2006). They, however, added that sleep did not alter the semiology and electrographic features of the seizures.

Minecan and colleagues studied video-polysomnographic data of 55 patients with seizures in sleep and revealed that NREM sleep, especially N2, facilitated both seizures and IEDs (Minecan et al., 2002). Similar results were obtained by Herman et al. in their study on refractory epilepsy patients (Herman et al., 2001).

Bazil and colleagues studied patients with focal epilepsy and in addition to making similar observations as the above mentioned, they noted that seizures during slow wave sleep lasted longer as compared to wake (Bazil and Walczak, 1997).

4.2. Concordance of VEEG localization with imaging data (and, therefore, potential role in localization)

This study is the first to report that among all patients undergoing VEEG as part of presurgical epilepsy surgery evaluation, seizures recorded during wake state had significantly higher localizing value than those recorded during sleep. On the contrary, for our subset of patients, in whom seizures were recorded both during wake and in sleep states, sleep seizures had much higher localizing value, for patients in TLE as well as ETLE categories.

As mentioned earlier, only one published study addresses the issue of VEEG localization in sleep versus wake states. Buechler et al. studied 28 seizure free post-operative patients with TLE, with seizures recorded during both wake and sleep states. For this selected group, their observations that sleep ictal EEG is four times more localizing than wake ictal EEG and also more focal as compared to wake; are similar to ours (Buechler et al., 2008).

The possible explanation for the difference in the localizing value of sleep seizures versus wake seizures, between the overall heterogeneous population of patients included in our study and the above mentioned subset of successfully operated patients with TLE in the quoted study, could be that there was a more balanced representation of patients with epilepsy arising from different locations in the cerebral cortex, with nearly a 2:1 ratio of patients with TLE versus ETLE.

The localizing value of VEEG was better during sleep seizures than wake seizures, in the subset of patients in whom seizures were recorded in both states.

There are two potential explanations for this finding. The first is similar to what Buechler et al. proposed in their study on ictal EEG recordings in patients with TLE during sleep versus wake states; which is reduction in muscle and movement artifacts at seizure onset, during sleep.

The other explanation is based on the fact that we are reporting the VEEG localization based on the combined information from clinical semiology, ictal EEG and interictal EEG of all patients. Nearly two-thirds of the patients included had TLE. Similar to published literature, many of our patients with TLE also, had subtle lateralizing or localizing features (generally the characteristic dyscognitive seizures) during seizures recorded in the wake state, while in the same patients, sleep seizures were often characterized by more obvious motor phenomena like unilateral limb dystonia and/or head version, due to the activating and generalizing effect of NREM sleep. Likewise, ictal EEG onset is also sometimes too focal and inconspicuous during wake state, especially in mesial TLE, often necessitating use of additional electrodes; while during

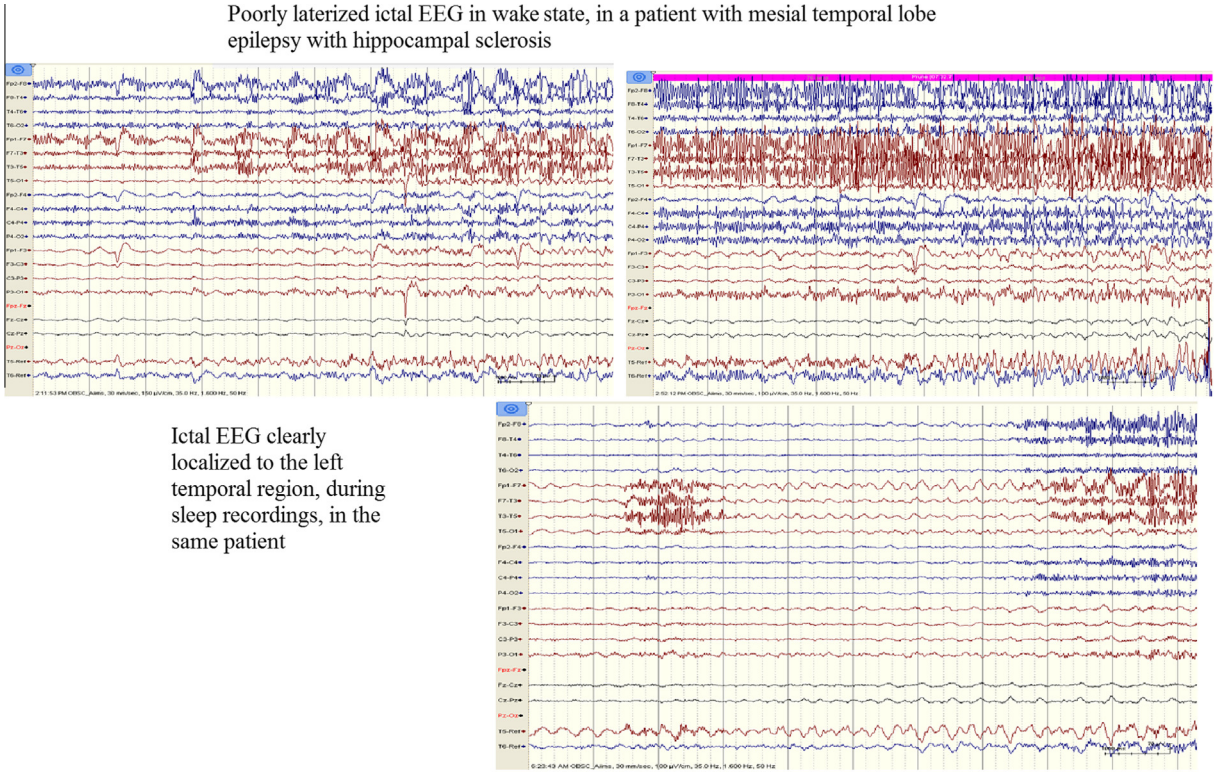

Fig. 2. Value of sleep ictal EEG for localization.

sleep, ictal EEG changes are more easily recognizable due to the activating effect of sleep often resulting in a wider field of distribution.

4.3. Role of interictal epileptiform discharges in localization

That IEDs are facilitated by sleep has been previously demonstrated by several authors (Sammaritano et al., 1991; Malow et al., 1998). We found that IEDs recorded in sleep, even in NREM, were significantly more focal as compared to wake and in many cases, were most useful in precise localization, when even ictal EEG could barely aid in lateralization alone. We found that discharges in REM were fewer, lost their sharp contour and were no more focal than those recorded during NREM sleep. These findings are different from those of Malow et al., who, in their study on 21 patients with TLE on stable AED treatment, described IEDs to be more common in NREM sleep and their distribution was more widespread, while IEDs though less frequent in REM, provided an accurate localization. These findings were on EEG-PSG recordings after at least 24 h of the last seizure. The same authors, however, reported in a later study, probably on the same patient group, reported that more than 60% (15/24) patients showed unilateral temporal IEDs and 11 out of 12 of these who then underwent surgery, were seizure free. All the others, who had bitemporal IEDs during NREM sleep had post-operative seizure recurrences. Hence, the authors concluded that sleep IEDs added prognostic data to epilepsy surgery evaluation, not provided by daytime EEGs (Malow et al., 1998). Our findings may differ from the former report, mainly because of our inclusion of a more heterogeneous patient population, with almost 1/3rd of the patients having ETLE; also our data represents observations, irrespective of AED tapering and seizure occurrence close to the IEDs noted. In addition, our sample size is much larger than both studies, even for the TLE subset.

4.4. Limitations

The main shortcoming of our study may be that we have not been able to analyze data separately for patients who have undergone epilepsy surgery. This will be the subject of future continuation of this research, and correlation of VEEG data in sleep versus wake, with surgical outcomes, would potentially add more value to our current observations.

5. Conclusion

This prospective VEEG-PSG study demonstrates the role of sleep versus wake state in the localizing value of different components of long-term VEEG recording for patients with medically refractory epilepsy. Our findings show that while wake state ictal EEG has more localizing value in a mixed group of patients, sleep ictal and interictal EEG is significantly more useful in patients who have seizures recorded both during wake and sleep states. In addition, IEDs recorded during NREM sleep have high localizing value.

Conflicts of Interest

None of the authors has any conflict of interest to disclose.

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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